(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 August 2002 (15.08.2002)

PCT

(10) International Publication Number
WO 02/063141 A1

(51) International Patent Classification[7]: F01K 23/04, 27/00

(21) International Application Number: PCT/SE02/00118

(22) International Filing Date: 24 January 2002 (24.01.2002)

(25) Filing Language: Swedish

(26) Publication Language: English

(30) Priority Data:
0100244-3 25 January 2001 (25.01.2001) SE

(71) Applicant *(for all designated States except US)*: **ADDPOWER AB** [SE/SE]; Metallgatan 12D, S-262 72 Ängelholm (SE).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **STRAND, Lennart** [SE/SE]; Metallgatan 12D, S-262 72 Ängelholm (SE).

(74) Agent: **NILSSON, Lennart**; Lennart Nilsson Patentbyrå AB, Ljungsjövägen 1298B, S-311 95 Falkenberg (SE).

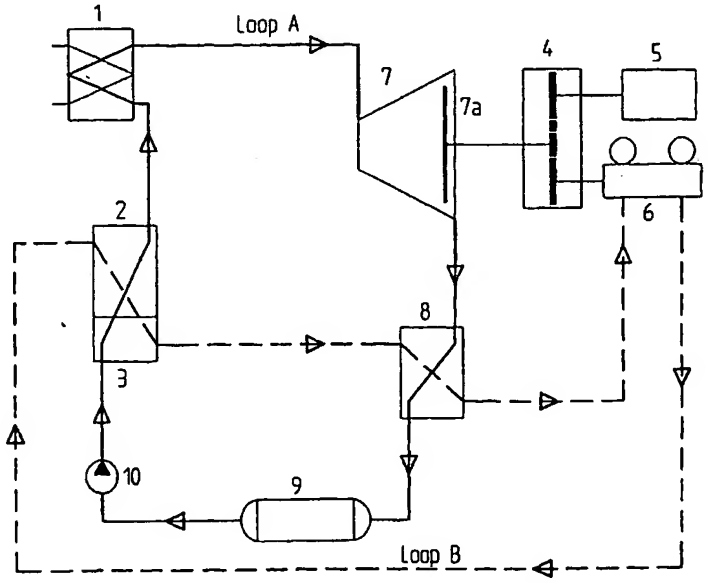
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: A METHOD OF CONVERTING THERMAL ENERGY INTO MECHANICAL WORK



(57) Abstract: The present invention relates to a method of converting thermal energy, e.g. waste heat of different types such as flue gas heat, etc., solar heat or other low value thermal energy, and so on, into mechanical work, e.g. electricity generation, in which an energy carrier is circulated in a first loop (A) for receiving heat from an external energy source and converting said addition into mechanical work by co-operating with a second energy carrier which is circulated in a second loop, the energy exchange between the energy carriers being carried out in a preheater/boiler and a condenser.

WO 02/063141 A1

A METHOD OF CONVERTING THERMAL ENERGY INTO MECHANICAL WORK

The present invention relates to a method according to the preamble to appended claim 1.

The environment is constantly deteriorating, often because of profligacy with resources, but also because of a lack of capability to take care of available resources. Thus, it is of great importance that the use of generated energy is improved. Electricity is the simplest energy form to convert into other energy forms and, hence, electricity has become that type of energy which is used most. Regardless of whether the electricity is generated by wind power, nuclear power or by renewable energy sources, it is very difficult to store electricity and recover it. In many industrial processes, the electricity is converted after use mostly into heat which is cooled off to no good. This takes place in the paper and pulp industry, in the steel industry, in cement manufacture and glass manufacture, and also in glass wool insulation manufacture, in chemical and petrochemical processes and large proportions of the supplied electric energy is obtained in the form of heat which is generally cooled down with the aid of coolant water to no benefit, but rather on many occasions to disadvantage and inconvenience, or is led off as hot flue gases.

The task forming the basis of the present invention is to realise a method of providing such low temperature thermal energy as is exemplified above and a plant for carrying out the method.

This task is solved according to the present invention in that the method indicated by way of introduction has been given the characterising features as set forth in appended claim 1.

The present invention makes possible the generation of electricity with the aid of waste heat or other low value energy or solar energy by means of which the degree of efficiency can be considerably improved as compared with that which is known in so-called Ranking processes, and it will not require that coolant water must remove large quantities of energy which is otherwise required for a Ranking cycle to function. Further, the present invention makes it possible that spent electricity can be recovered at low temperatures with a high degree of efficiency which makes it possible for an investment to be profitable.

The present invention will be described in greater detail hereinbelow with reference to the accompanying drawing which shows a diagram of a plant for carrying out one embodiment of a method according to the present invention.

The plant illustrated on the drawing has a primary loop A and a secondary loop B. The loops A, B are closed. In the primary loop A, an energy carrier or vehicle is circulated containing a mixture of hydrocarbons which are non-toxic and have no harmful effect whatever on the ozone layer or so-called greenhouse effect. The energy carrier or liquid in the primary loop A has an operating pressure which may vary between 20 and 30 bar and a vaporisation temperature which varies between 50 and

70°C. Since the entropy curve is powerfully parabolic in formation, there will be obtained a large enthalpy addition on superheating in the gas phase and the superheating can take place up to approx. 95°C. Under an isenthropic expansion of the energy carrier in the primary loop A, the pressure falls drastically to approx. 2-3 bar and the condensation takes place only when the temperature has been reduced to –20°C to –30°C. The stability in the hydrocarbon mixture is of major importance and it is highly crucial that the dew point curve is homogeneous so that reliability can be attained via partial pressure measurement change related to the relevant dry temperature.

In the energy carrier in the secondary loop B, there is also included a mixture of hydrocarbons, although this energy carrier operates with a very slight pressure difference, the pressure differences being less than 1 bar. The temperature difference should be at least 5°C and if the condensation in the primary loop takes place at –30°C, the vaporisation thus takes place in the secondary loop at –35°C.

In the primary loop A, the energy carrier is driven which is characterised in that it has a very low boiling point with the aid of a pressuriser pump 10 and in such a manner that the temperature of the energy carrier is increased in a pre-heater 3 to corresponding to the boiling point of the energy carrier at a constant pressure in order in a boiler 2 to be brought, with the aid of additional supply of energy, to be totally vaporised, and finally in a superheater 1 and enthalpy increase is effected to a temperature which corresponds to that point which implies that, when the energy carrier via an isenthropic expansion has undergone a temperature reduction this may not be below the dew point of the energy carrier but a liquid condensation must first take place when the expanding gas meets the energy carrier of the same type circulating in the secondary loop B which as a result of expansion is at a lower pressure that in a closed cooler 8 is caused to vaporise and at the same time as the gas from the expander 7 condenses. The enthalpy in the gas is reduced and transferred to the second energy carrier which is vaporised and converts into gas and the process is made possible thanks to the work which is carried out in the expander 7 which entails that a wheel 7a provided with vanes sets a shaft in motion at high speed which, via a gearbox 4, changes down from shafts departing from the gearbox 4 which are connected partly to a generator 5 and partly to an apparatus 6 which, with a moderate effect of approx. 1 bar, raises the pressure of the gas which had been vaporised in the cooler 8 where it had been in indirect contact with the gas which had departed from the expander 7. The energy is recycled when the condensate is once again vaporised in a boiler 2. The process takes place in closed cycles.

Apart from minor losses, all external energy supply will be transferred via the vane wheel 7a to a shaft which via the gearbox 4 drives the generator 5 which generates electricity, and the pressure increase which is required of approx. 1 bar requires very slight work so that only approx. 15% of the supplied power is consumed for this pressure increase. Of the external supplied energy, it is thus calculated that approx. 80% will become electricity and that none of this supplied energy need to be cooled off, which is a requirement for corresponding apparatuses to function.

CLAIMS

1. A method of converting thermal energy, e.g. waste heat of different types such as flue gas heat, etc., solar heat or other low value thermal energy, and so on, into mechanical work, e.g. electricity generation, **characterised in that** an energy carrier is circulated in a first loop (A) for receiving heat from an external energy source and converting said addition into mechanical work by co-operating with a second energy carrier which is circulated in a second loop, the energy exchange between the energy carriers being carried out in a preheater/boiler and a condenser.

2. The method as claimed in claim 1, **characterised in that** a part of the energy in the first energy carrier is transmitted to the second energy carrier after conversion of said energy portion into mechanical work.

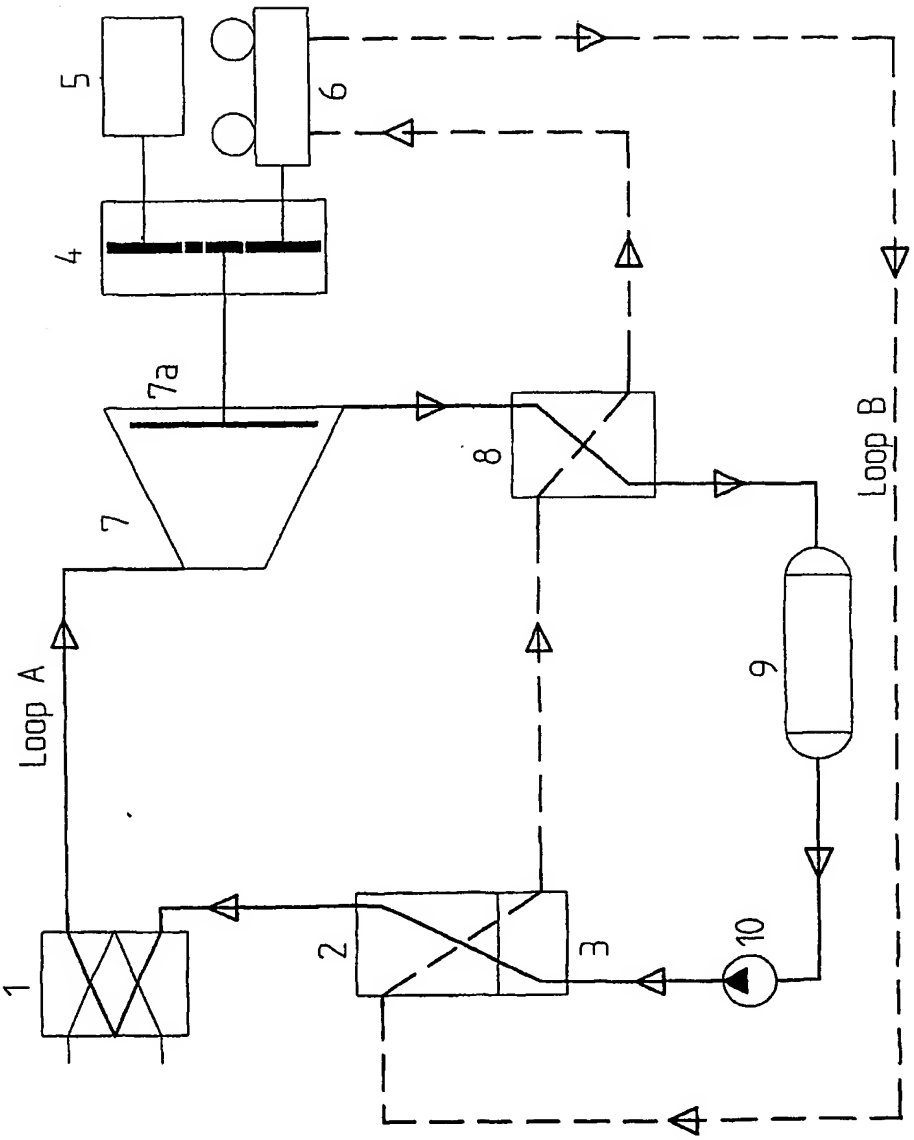
3. The method as claimed in claim 1, **characterised in that** the first energy carrier in the first loop is heated in a preheater to its boiling point, is vaporised in a boiler with the aid of energy from the second energy carrier in the second loop (B) and is heated in a superheater for increasing the enthalpy of the first energy carrier.

4. The method as claimed in claim 3, **characterised in that** the enthalpy of the first energy carrier is increased to a temperature which permits an isenthropic expansion to a temperature which is higher than the dew point of the energy carrier.

5. The method as claimed in the preceding claims, **characterised in that** the first energy carrier is expanded for converting energy from the first energy carrier into mechanical work.

6. The method as claimed in claim 5, **characterised in that** the first energy carrier is condensed after the expansion under reduction of the enthalpy for transferring energy to the second energy carrier.

7. The method as claimed in claim 6, **characterised in that** the second energy carrier is vaporised in order thereafter to be given higher pressure in a pressuriser which is driven by means of a part of the mechanical work which is extracted from the first energy carrier while a second major portion of the mechanical work drives an electricity generator.


5
6
4
7a
7
8
Loop B
Loop A
9
1
2
3
10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 02/00118

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F01K 23/04, F01K 27/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F01K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SE 311022 B ("LICENCIA"TALáMáNYOKAT ERTEKESITó VáLLALAT), 27 May 1969 (27.05.69) --	1-7
X	GB 2162584 A (ORMAT TURBINES (1965) LTD. (ISRAEL)), 5 February 1986 (05.02.86) --	1-7
X	US 3413805 A (L. HELLER ET AL), 3 December 1968 (03.12.68) --	1-7
X	US 4146057 A (J. FRIEDMAN ET AL), 27 March 1979 (27.03.79) --	1-7

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 April 2002	30 -04- 2002
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Sune Söderling / MRo Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 02/00118

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5437157 A (L. BRONICKI), 1 August 1995 (01.08.95) -- --------	1-7

INTERNATIONAL SEARCH REPORT

Information on patent family members

28/01/02

International application No.
PCT/SE 02/00118

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
SE 311022 B	27/05/69	CH 401097 A	31/10/65
		DE 1401466 A	24/10/68
		FI 41565 B	01/09/69
		GB 979237 A	01/01/65
		NO 119594 B	08/06/70
GB 2162584 A	05/02/86	GB 8518472 D	00/00/00
		MX 157254 A	08/11/88
		NZ 212813 A	30/04/87
		US 4542625 A	24/09/85
US 3413805 A	03/12/68	CH 446397 A	15/11/67
		DE 1551245 A	06/05/70
		FI 44628 B	31/08/71
US 4146057 A	27/03/79	NONE	
US 5437157 A	01/08/95	CA 2155654 A	18/08/94
		GB 2290610 A,B	03/01/96
		GB 9516604 D	00/00/00
		WO 9418515 A	18/08/94
		US 5483797 A	16/01/96
		US 5497624 A	12/03/96
		US 5526646 A	18/06/96
		US 5531073 A	02/07/96
		IL 101002 A	28/01/01
		PT 100139 A,B	29/04/94
		US 5660042 A	26/08/97
		US 5839282 A	24/11/98
		CN 1097240 A	11/01/95
		IL 107117 D	00/00/00
		JP 6341367 A	13/12/94
		MX 9306132 A	29/04/94
		NZ 248730 A	26/03/96
		RU 2126098 C	10/02/99
		US 5970714 A	26/10/99
		US 6212890 B	10/04/01
		CN 1097239 A	11/01/95
		IL 107116 A	04/08/96
		JP 6341368 A	13/12/94
		MX 9306129 A	29/04/94
		NZ 248729 A	26/03/96
		RU 2121118 C	27/10/98
		US 5671601 A	30/09/97